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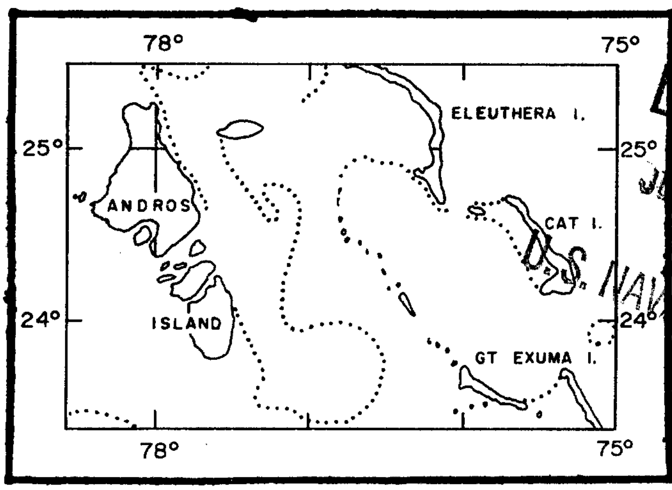
IR NO. 69-57

INFORMAL REPORT

SHALLOW WATER AMBIENT NOISE LEVELS IN THE TONGUE OF THE OCEAN, BAHAMAS, FALL OF 1965 AND SUMMER OF 1966



AUGUST 1969

NAVAL OCEANOGRAPHIC OFFICE
WASHINGTON, D. C. 20390

INFORMAL REPORT

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ABSTRACT

Ambient noise was monitored in shallow water east of Andros Island, Tongue of the Ocean, in November and December 1965 and September 1966. Data were collected with an encapsulated, self-recording device and a stand-mounted hydrophone connected by cable to shore-based instrumentation.

The prime noise generator was found to be snapping shrimp. Shrimp noise was high during light winds and low during winds approaching gale force. During winds of whole gale force, a sevenfold increase in noise level can be expected over that observed for normal weather conditions. Shipping was an insignificant contributory noise source at frequencies in the 5 - 10 kHz range. The noise level was slightly higher during cold weather months as indicated by the November-December 1965 mean of -55.5 db at 10 kHz and the September 1966 mean of -63.3 db at 10 kHz.

(Compilation of the data and illustrations for this report were completed by Mr. William J. Reaves, Jr., prior to his death in July 1968. The report was consolidated by Mr. J. S. Woodson, Nearshore Surveys Division, Oceanographic Surveys Department.)

This report has been reviewed and is approved for release as an UNCLASSIFIED Informal Report.

L. B. BERTHOLF
Director, Nearshore Surveys Division

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I. INTRODUCTION

During the periods 8 November through 10 December 1965 and 3 through 6 September 1966, acoustic monitoring was accomplished in the Tongue of the Ocean (TOTO) in the shallow water east of Andros Island. The data were collected for the AUTEC (Atlantic Undersea Test and Evaluation Center). Signal receiver-recorders were used for automated data collection.

In the September 1966 survey, a back-up system also was utilized. The need for this double monitoring had been demonstrated in the fall 1965 implant when intermittent readings caused gaps in the monitored data. The two systems employed were the Minneapolis-Honeywell Ambient Noise Capsule (M-H Capsule) and the Shallow Water Acoustic Monitor (SWAM) designed by William J. Reaves.

The capsule functioned satisfactorily during the 1965 survey and for about half the time during the 1966 survey. The SWAM system provided back-up and a check on the time-integrated type readout of the capsule.

A comparison of the db pressure levels versus time between the capsule and SWAM systems reveals the similarity of the data (see Figure 1). Comparisons can be made only in broad terms because the

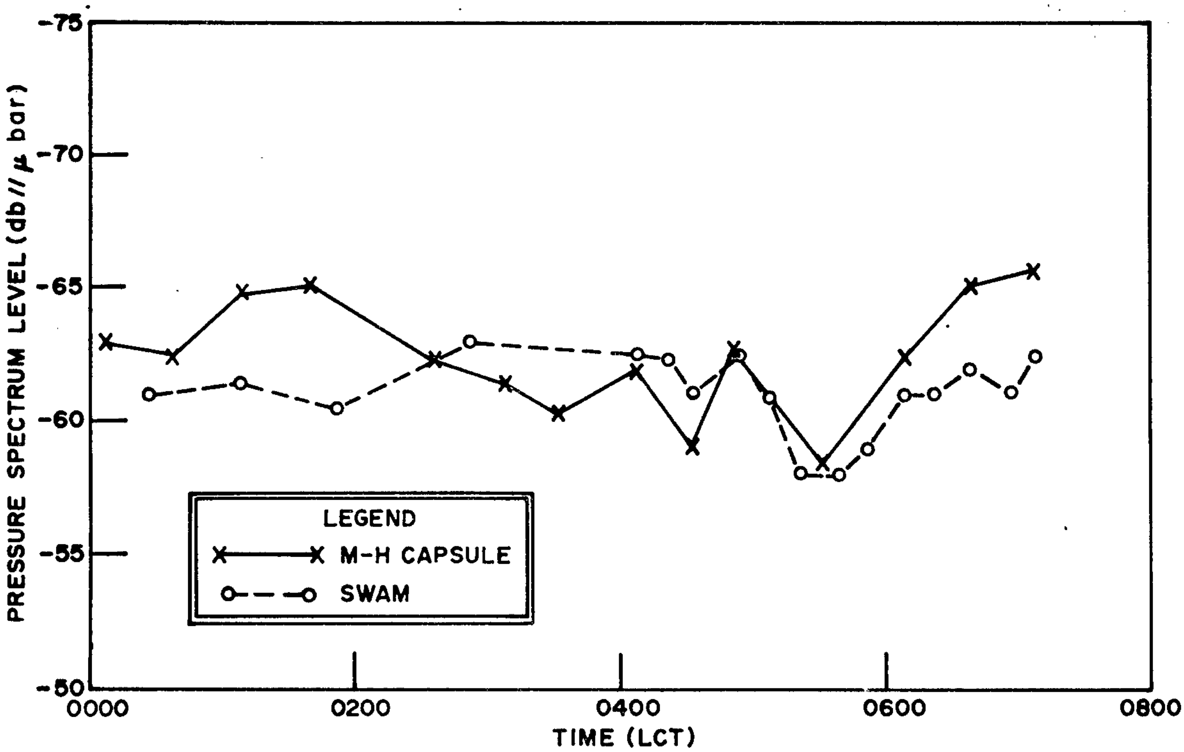

FIGURE 1. A 7-Hour Comparison of M-H Capsule and SWAM Data.

capsule integrates its data over a time period prior to recording, whereas, SWAM readings are instantaneous amplitudes. Also, a definite real time relation is obtained in capsule data by photographing a clock at each data cycle, but in SWAM data, only time notations are made on a moving tape. The comparison does establish, however, that both the highest and lowest db pressure levels obtained from SWAM are substantiated by the capsule.

II. SYSTEM DESCRIPTION AND USE

A. Ambient Noise Capsule.

This encapsulated, battery-powered system was used at High Cay and Site 2 shown in Figure 2. Except for the hydrophone, the capsule's modules, circuitry, and batteries are housed in a cylindrical, buoyant hull (Figure 3).

Power is automatically supplied to the system at chosen intervals of either 15, 20, 30, or 60 minutes for a total on-period of 2 minutes. Underwater sound received by the hydrophone for a 1-minute period is amplified and filtered into four discrete frequency bands centered at 5.4, 10.5, 22, and 40kHz. Each bandpass filter has a nominal 15 percent band width. Sound levels measured in each band are integrated and displayed on a digital readout matrix by illumination of banks of translucent indicators. The illumination of the matrix indicators exposes a frame of film on a shutterless, single frame camera. A phosphorescent clock and counter display time and frame number to the film. After exposure of the frame, the film is automatically advanced in preparation for another cycle. Upon completion of each fourth cycle of measurements at the 5.4 - 40kHz range, a magnetic tape recording is made of ambient noise in the 0.1 - 3kHz range.

The M-H capsule was chosen for this shallow water investigation because it has the inherent advantages of a self-contained, automatic oceanographic instrument. The difficulties generally encountered with an over-the-side system, i.e., minimizing self-generated noise such as ships' noise and cable strum, are absent when employing the capsule as a monitoring device.

The ambient noise capsule for both the 1965 and 1966 surveys was programmed to sample and record (gray code) ambient noise every 15 minutes. Acoustic data were obtained continuously from 17 November through 4 December 1965 from a point near High Cay where the capsule was anchored 18 feet off the bottom in 50 feet of water. During the 1966 implantment, when the capsule was moored 8 feet off the bottom in 15 feet of water at Site 2, divers reported that the capsule was bottoming at low tide--presumably caused by currents. A noise versus tide plot also indicated bottoming. The capsule was planted at noon on 3 September and was recovered on 13 September. However, the data appear to be valid only through noon on 5 September because of a suspected drop in battery power.

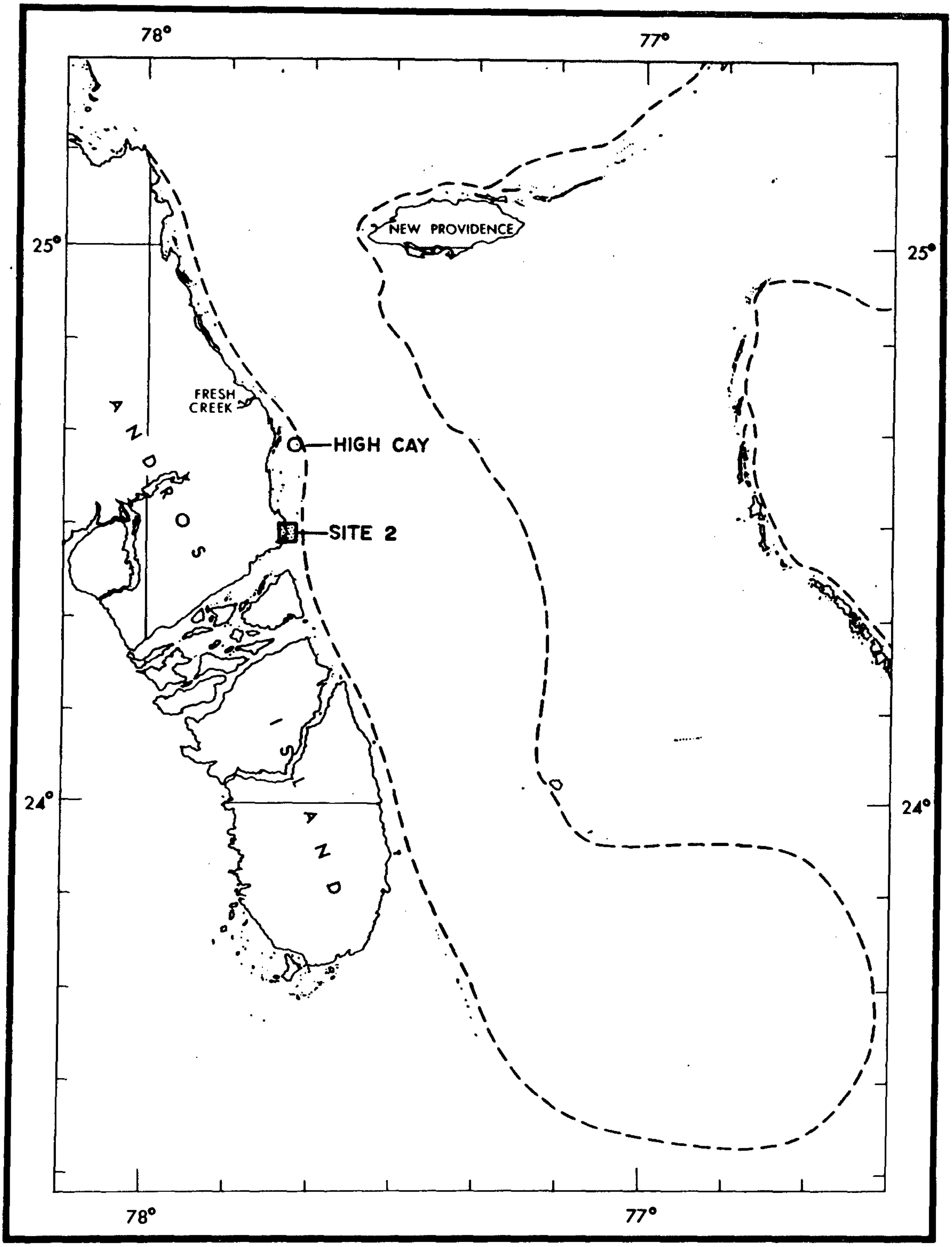

FIGURE 2. Observation Sites.

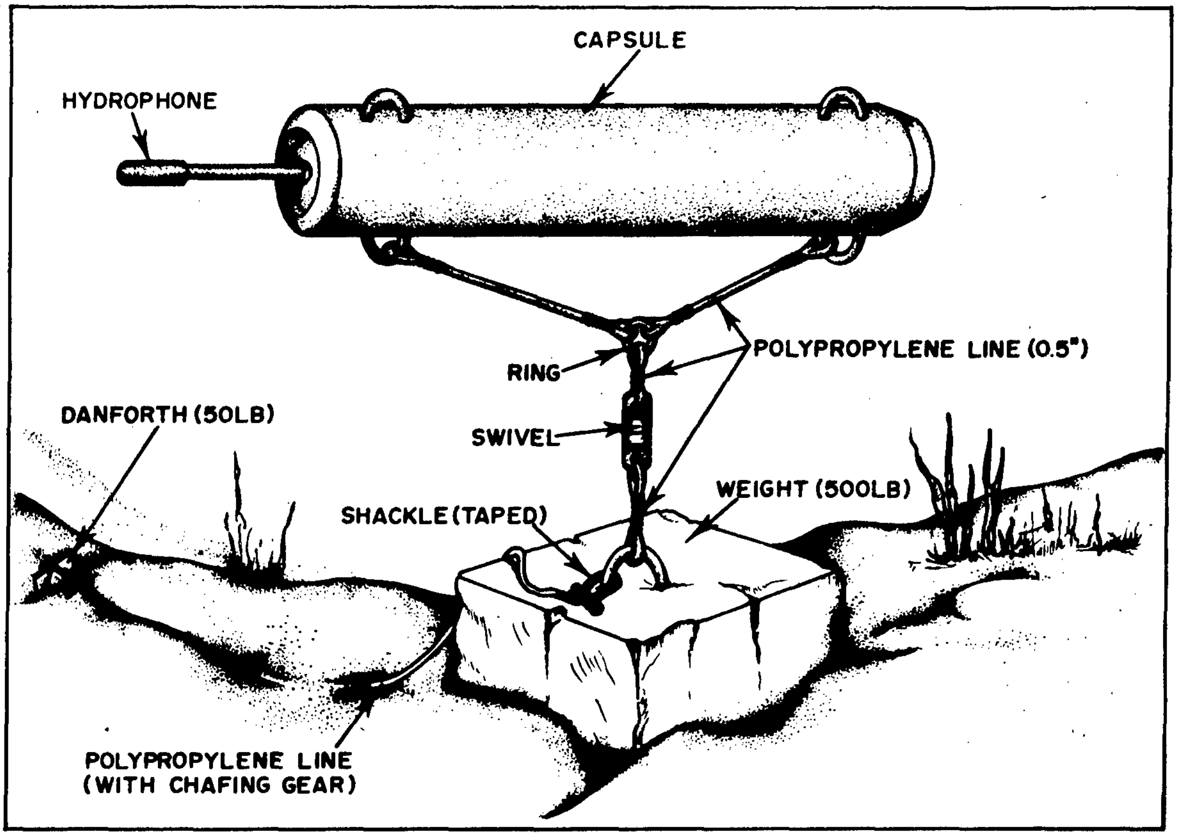

FIGURE 3. Capsule Mooring Method.

While the capsule was on station during the 1965 survey, meteorological data were observed and recorded as part of normal operations at the following stations:

1. AUTEC Site 2.
2. International Airport, New Providence Island, Bahamas.
3. USS LITTLEHALES (AGSC 15) on various oceanographic stations in the TOTO.

B. SWAM System.

The SWAM system's hydrophone (Figure 4) was installed off Andros Island 5,000 feet from shore and 750 feet north of the AUTEC Site 2 channel (Figure 2). (The M-H capsule was installed 50 feet away.) Water depth at the hydrophone location was 15 feet. A cable, 5,000 feet long, connected the hydrophone with shore-based instrumentation. The main shore-based components of the system were the following: Preamplifier, amplifier, filter (variable one-third octave band pass), decibel meter, and strip chart recorder. The shore electronics were located in the instrument trailer of the NAVOCEANO installation at AUTEC Site 2. Noise was measured daily at 0050, 0600, 1200, and

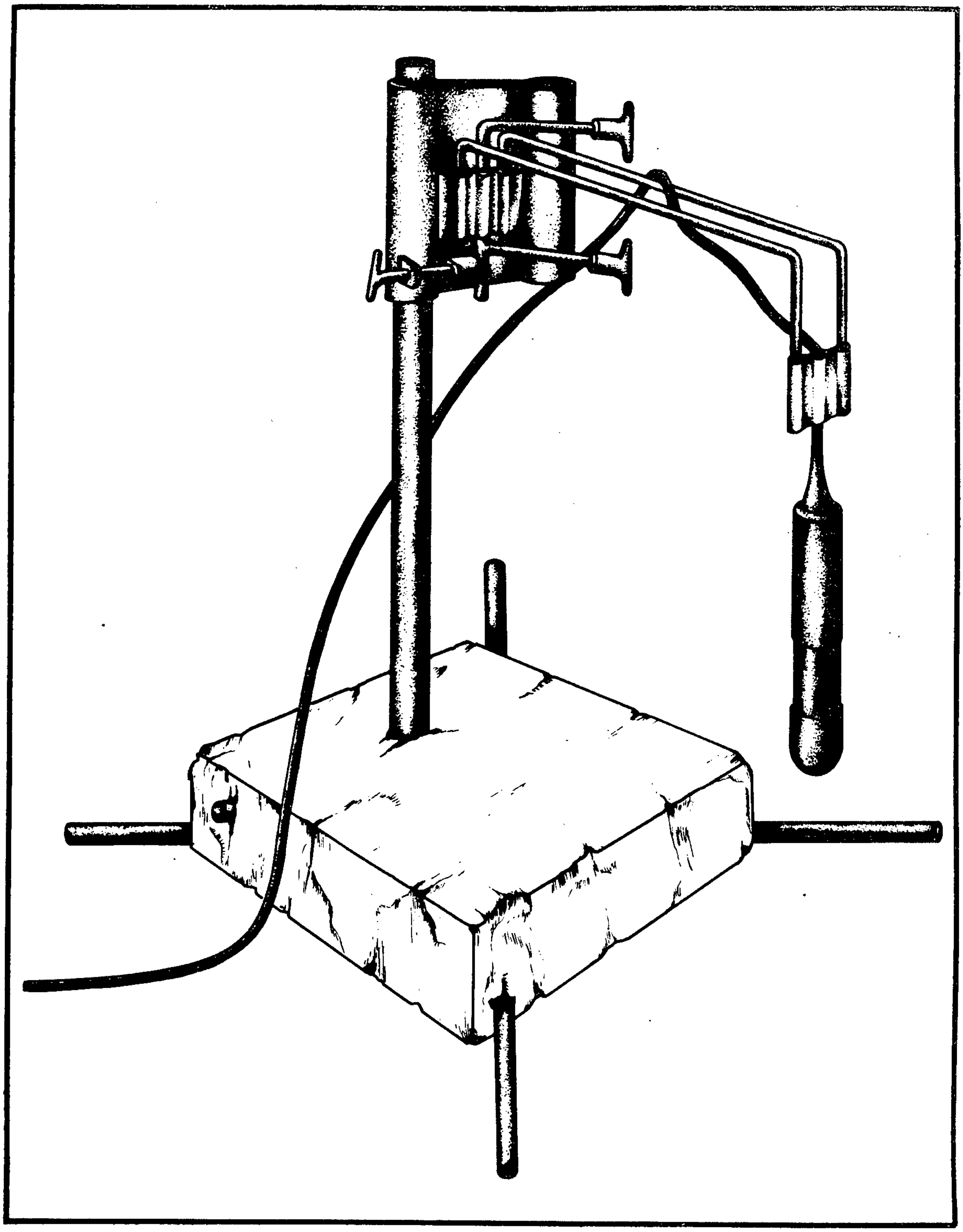

FIGURE 4. SWAM System's Hydrophone Installation.

1800 hours Local Civil Time (LCT) and during extremes of contributory environmental conditions. (In preparing this report, it has become clear that monitoring environmental changes is more important than timed measurements and that all conditions must be monitored simultaneously for a significant time span; i.e., wind, temperature, tide level, noise level, and sea state must all be obtained simultaneously, and the data records must be well annotated as to the time that a change appears in the above phenomena.) At Site 2, tide and meteorological observations accompanied each acoustic measurement. SWAM observations were made intermittently on this station from 2 June 1966 until 18 February 1967.

The SWAM acoustic data collected at Site 2 were grouped by periods of time. The following factors necessitated this type of grouping:

1. The rapid accumulation of fouling on the hydrophone with time. The decreasing sensitivity of the hydrophones, primarily due to fouling, caused a slight decreasing trend in the levels of the hydrophone output.

2. The rotation of personnel at Site 2 made it necessary that the system be compact and exhibit operational simplicity. The majority of the data was acquired with a db meter monitoring at 10kHz; therefore, levels recorded were "eye-balled" averages of a fluctuating meter. Comparing data collected by two or more observers could very likely produce an unknown error in the analysis. For this reason, a Sanborn recorder was patched into and calibrated as part of SWAM prior to the installation of the M-H capsule.

With the effects of the above mentioned factors in mind, data were collected to observe short term changes and deviations rather than absolute spectrum levels. No long-period analysis has been attempted.

III. DISCUSSION

A. General.

The noise measurements were made as part of an overall objective to establish the effects of ambient noise influences on the AUTEC range operations. The summer-fall noise levels are indicated for reef environment in the frequencies monitored, and noise levels are shown for the 40 - 50 mph winds of Hurricane Inez. Noise relationship to wind and other factors were investigated and are discussed below.

B. Noise from Snapping Shrimp.

A vast colony of snapping shrimp inhabits the shallow waters surrounding the TOTO. The crackling sound produced by beds of these crustaceans dominates the noise monitored in audio frequencies higher than 5kHz. The snapping shrimp crackling was easily detected at ranges less than 2 miles from the 30-fathom contour. This sound was in evidence on all taped records from the capsule, and it is therefore assumed that snapping shrimp in quantity were in the immediate vicinity of the hydrophone during the measurement interval. It is also assumed that shrimp are the major contributors to ambient noise in the shallow waters surrounding the TOTO. The appendix contains a summary of ambient noise spectra in the presence of snapping shrimp. See chapter 16 of Underwater Acoustics Handbook for other discussion of snapping shrimp.

The most predictable variation in the monitored noise levels is that associated with changes in wind velocity. As indicated by the capsule data for the 6-day period monitored between 20 and 25 November 1965, for winds below gale force, the noise level will be high during low wind speeds (0-6 knots) and low during higher wind speeds (15-25 knots) (Figure 5). Additional substantiating data are presented on pages 24 and 25.

The theory advanced for the decreased noise level on the shallow water during high but below gale force winds is that shrimp tend to "quiet down" during high winds. There is the possibility that shrimp do not decrease noise generation but rather burrow into the bottom and produce less instrument discernible sound.

It is significant that the data in this report are not in agreement with the conclusions drawn from six major ambient noise surveys conducted in the TOTO by Columbia University and the University of Miami as to the prime nature of variation in shrimp generated noise levels. The university laboratory data substantiated the existence of high nighttime and low daytime shallow water noise levels. Each university completed three surveys during the period 1943-1959. Factors which may account for the differences are: (1) that SWAM and capsule data are from longer time span measurements, (2) the absence of ship or small boat frequently in the vicinity of the monitored area, (3) a much higher percentage of bottom mounted acquired data as opposed to lowered hydrophone measurements, and (4) a larger volume of data from one station.

The shallow water sound level variation is different from that recorded in a deep water implant of the capsule (February 1965) off Fresh Creek where the noise level was significantly higher at night than during daylight. The capsule on the February 1965 implant was placed at the 250-foot depth in 4,500 feet of water. The periodicity of the February variation is attributed to the abandonment of deep water by marine life for the more lucrative feeding area of the photosynthesized zone during daylight.

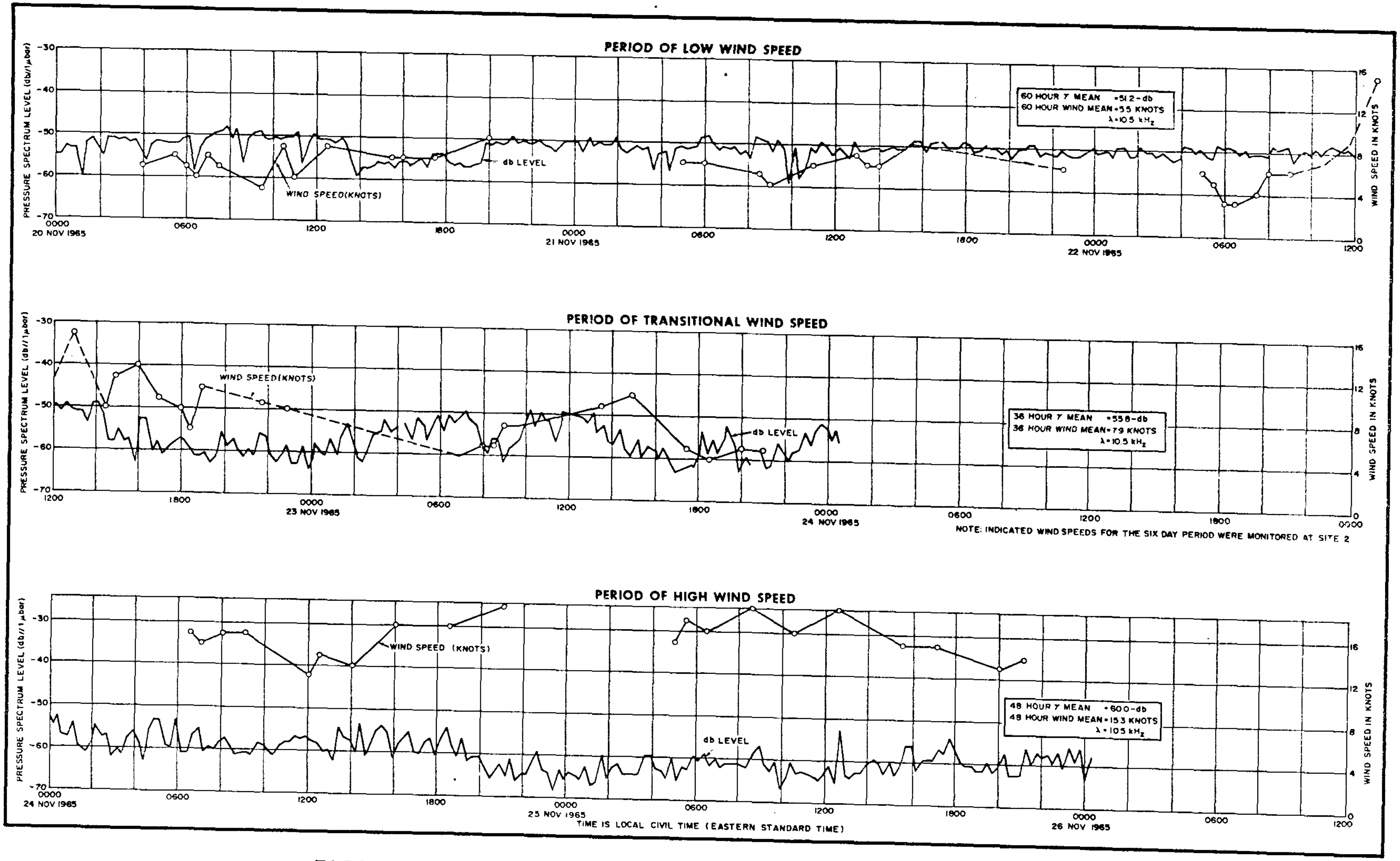

FIGURE 5. Capsule Noise Amplitudes versus Varying Wind Speeds.

C. Noise from other Marine Life.

A wide range of marine life inhabits the TOTO, and noise from soniferous fish has been detected throughout the area. A literature survey of the TOTO by Lieutenant Kral, USN, NAVOCEANO IMR 0-45-62 of June 1962, documents the marine life. Turtles, fish, and mammals contribute to noise, but as has been noted, the dominant contribution is made by snapping shrimp.

D. Noise from Rain.

An effort was made to establish the influence of rain as an isolated contributor to the ambient noise level. The meteorological data were searched for periods of rainfall of at least an inch in which wind levels remained low. No such periods were discovered during the period monitored by the M-H capsule for either the November 1965 or September 1966 implants. The SWAM system monitoring on 27 October 1966 (between 1656-1705 hours) covered the only rainfall where the rain gage and SWAM were simultaneously operating. The better period to have monitored would have been between 1445 and 1515 hours, but the Sanborn recorder was not turned on until 1656 hours or near the end of the second accumulation (Figure 6). The noise levels measured during rainfall showed an increase in level compared to noon data. There is no certainty from examination of the data when rain impacted in the hydrophone area, a mile from the rain gage.

In this case, the SWAM monitoring coincided with an increasing wind velocity (from 5 kns to 11 kns), and from previous analysis, increasing winds would indicate a noise decrease and not an increase. There is enough indication to warrant further study of rainfall as a variant in noise levels for shallow water. The more sophisticated meteorological monitoring equipment now at AUTEC sites will greatly aid in any future study. A 1967 text, "Principles of Underwater Sound for Engineers", contains discussion and illustration of rain as a noise contributor.

E. Noise from Ships.

Ship generated noise was investigated as the possible cause of frequent short term variations in levels during midday hours. This phenomenon occurred over the entire range of frequencies monitored by either system with short period variations nearly as high as long period changes. The conclusion was reached that in or near the shallow waters adjoining the TOTO shipping is an insignificant contributory noise source at frequencies in the 5 - 40kHz range.

Examination of data, collected during the time that LITTLEHALES was directly above the capsule and when LITTLEHALES' range was over 4 miles with no sighted vessel closer to the capsule, revealed the following: In bands centered at 10.5, 22, and 40kHz, there was a

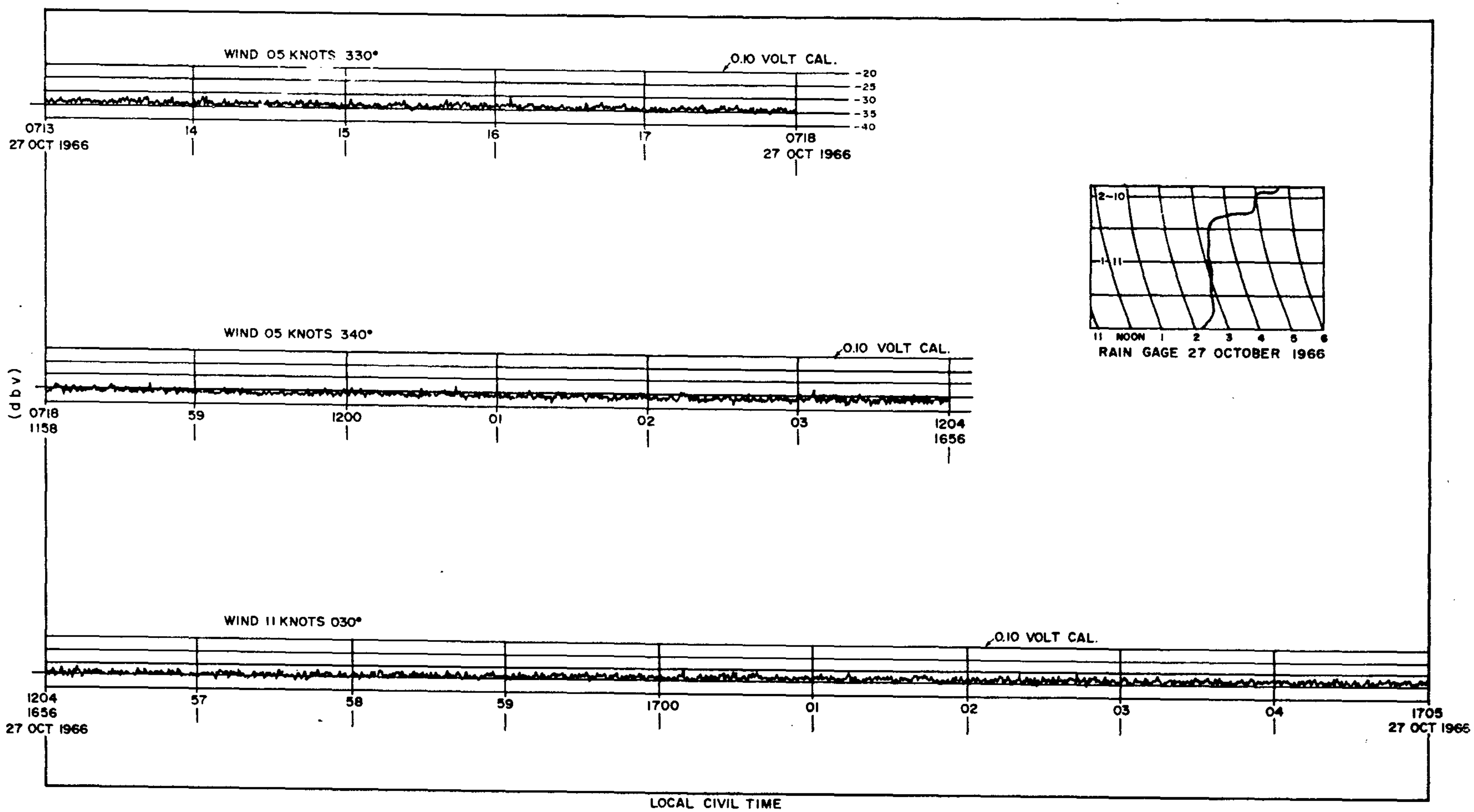

FIGURE 6. SWAM and Rain Gage Records for 27 October 1966.

slight tendency for noise levels to increase as the range to LITTLEHALES increased. The 5.4kHz spectrum level tended to weakly decrease as the range to LITTLEHALES increased. (see Figure 7).

Measurement and analysis of LITTLEHALES' acoustic signature while the capsule was being installed showed the peak output at a frequency less than 0.1kHz and spectrum levels decreasing rapidly with increasing frequency. Assuming that any ships navigating the waters near the station have signature characteristics similar to LITTLEHALES, then noise generated by ships is not a major variant in the data.

The noise variation cited above is less than 3 db. The capsule data short term variations (15-minute interval) were observed to have a range as high as 11.5 db. This large range was observed at night, a time when ship traffic is unlikely to be in the vicinity of the reef. As with high sea state, the migratory and acoustical activity of a bed of snapping shrimp would seemingly be affected by the presence of shipping. If the bed tended to "quiet down" and/or move away from noise or turbulence resulting from shipping, an explanation would be furnished for the trend of variation presented in Figure 7.

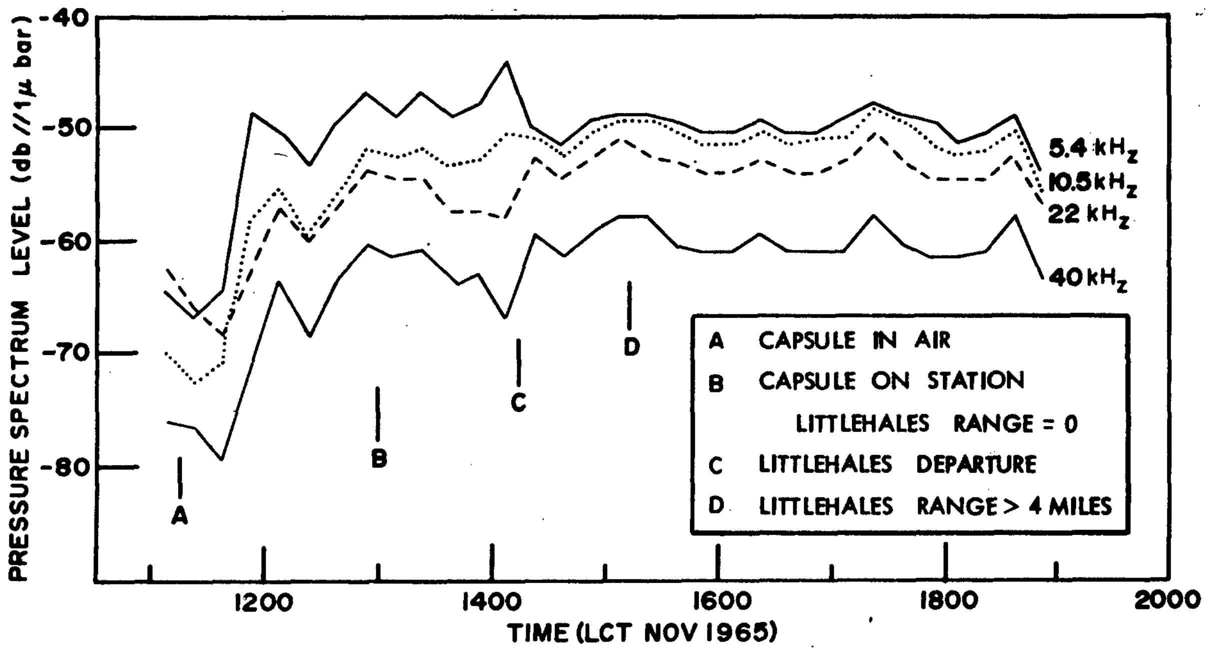

FIGURE 7. Shallow Water Ambient Noise in the Presence of Shipping (TOTO).

F. Noise Variation with Wind Speed.

Earlier in this report, the noise levels as generated by shrimp were related to wind speeds and found not to change radically up to gale force winds. Hurricane Inez, passing Andros Island during 2 - 4 October 1966, provided an opportunity to relate sound levels to higher winds at the 15-foot depth near the reef. The hurricane traveled north through the Florida Straits to Abaco Island and then into the Gulf of Mexico via the same route.

In relating these data to the AUTEC operations, it must be noted that under such extremes of wind, rain, and sea state the range will be non-operational. This rise in noise level is applicable only to fleet combat units in a nearshore environment.

The noise levels recorded, (Figure 8), show a peak just after 1600 hours on 2 October 1966, before the low barograph reading. During this period, winds were out of the southeast, a long fetch direction. All later wind directions moved nearer west, or to minimum fetch, and account for the noise level decrease since winds continued over 40 knots in very heavy rain showers. The anemometer also is placed on the lee side of the island by the westerly winds.

The SWAM level conversions, voltage to dbv, may be determined from the table below:

1.0 volt = 0 db	0.050 volt = -26.0 db
0.10 volt = -20 db	0.030 volt = -30.5 db
0.07 volt = -23 db	0.015 volt = -36.5 db

The noise generated during the storm is about seven times the intensity as shown in Figure 6. An increase of this magnitude would carry well offshore, but the same overtopping of deep water waves occurring in the open sea would cause a comparable noise increase.

G. Bottom Conditions.

Among the many factors influencing the intensity of noise is the stability of conditions in which the major noise generator, the snapping shrimp, exists. The Andros lagoon and the deeper bottom, seaward of the reef adjacent to the TOTO, provide the rough topography, coral heads, caves, shells, rocks, kelp, and vegetable growth which favor the growth of shrimp colonies.

The depths best suited to shrimp bed development, 5 to 30 fathoms, along the outer platform are covered in great detail in NAVOCEANO TR-189 of May 1966. The authors used SCUBA and Perry Cubmarine (PC3-B) to obtain photographic and artistic documentation.

The ruggedness of the bottom, size of coral and rock outcrops, trenches, and caves probably account for the lack of significant change during winds of moderate velocity since the features would decrease current velocities. The wind driven wave cannot bottom in the deeper portions of the TOTO, but 1-knot currents to 70 fathoms could be driven onto the escarpment top, there to be reflected, refracted, and broken up.

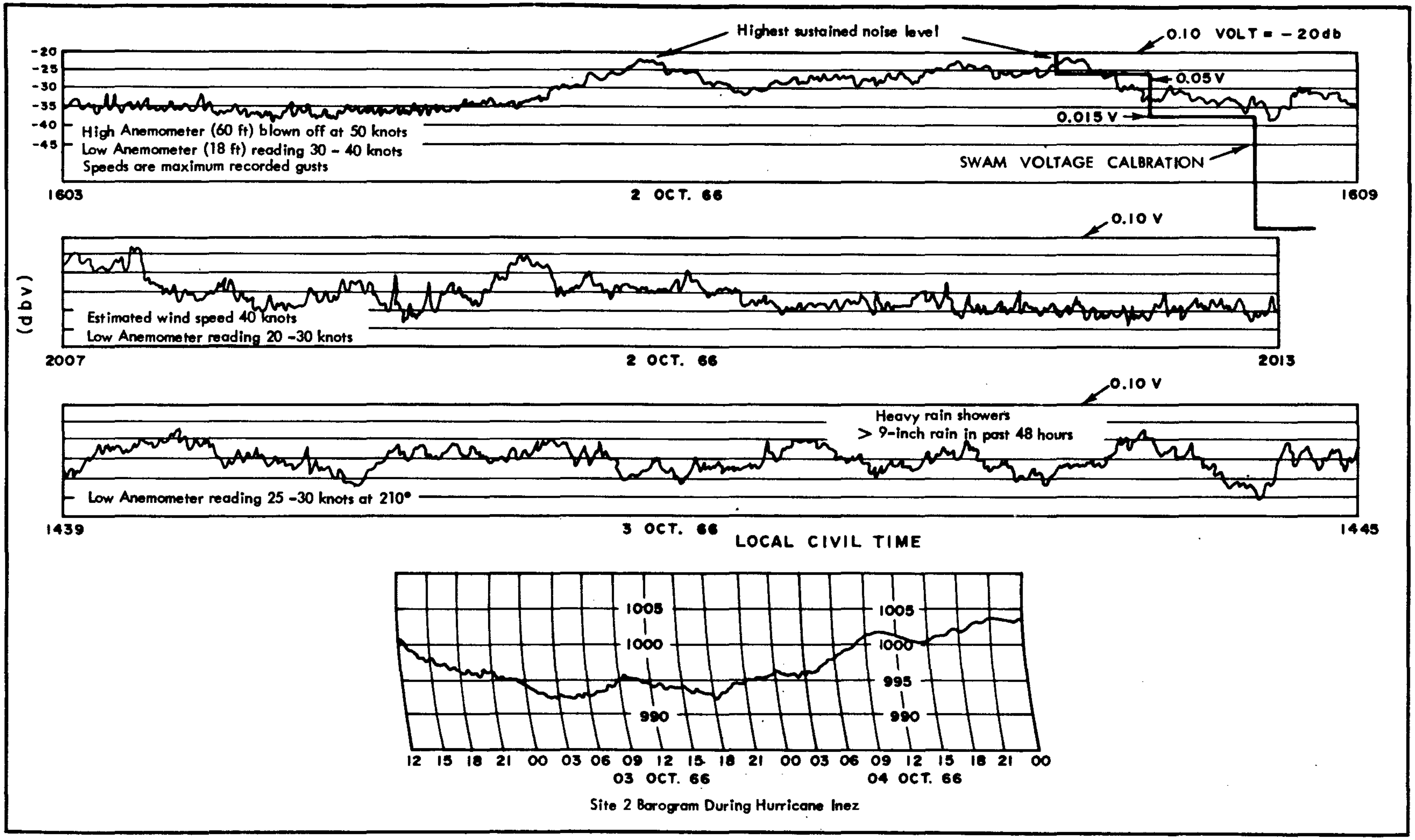

FIGURE 8. The Effects of Strong and Whole Gale Winds on SWAM Recordings.

To date, there has been no monitoring of temperature seaward of the reef and short of the dropoff. The best information available at NAVOCEANO is provided by the Office's SCUBA diver oceanographers who, since 1964, have made many dives in and around the reef and drop-off areas. The divers have found that in areas of 5- to 30-fathom depths seaward of the reef the water column essentially is isothermal top to bottom, and furthermore, the currents noted have been those pouring over the escarpment and sliding down the face into deep water. These currents could be water carried by tide and by rip tides from the beach areas and would have little temperature differential but higher salinity and density.

Historically, the top 50 fathoms of the TOTO water is isothermal with a summer-winter variation of 5°C. There is nothing to indicate that the deep, cool water of the TOTO is forced by currents impinging on the sides of the basin to rise to the escarpment top. It appears that the temperature in the shrimp beds does not radically change. Comparison of November 1965 and September 1966 capsule data indicates slightly higher noise levels in the 1965 data.

IV. CONCLUSIONS

The prime contributor to normal or typical shallow water noise levels in waters surrounding the TOTO is marine animal life. The noisiest among these marine animals is the snapping shrimp. Shrimp noise will be high in light winds and low during winds approaching gale force. This variation of noise level is different from that for deep water in the TOTO where marine life is again the prime contributor but where measured noise levels are diurnal, being quieter during daylight hours. (Unreported February 1965 M-H capsule data.)

During winds of whole gale force, a sevenfold increase in noise level can be expected over that observed for normal weather conditions. The relationship of this increase to open ocean noise levels can not be determined from the data, but the increase is sufficient to mask ship generated noises.

Shipping is an insignificant contributory noise source at frequencies in the 5 - 40kHz range for the shallow waters surrounding the TOTO.

Rain, as an independent contributor, probably does significantly raise the noise level in the shallow waters, but this report does not contain enough information to substantiate this hypothesis.

The noise level along the east coast of Andros Island is slightly higher during cold weather months as indicated by the November - December 1965 mean of -55.5 db at 10kHz and the September 1966 mean of -63.3 db at 10kHz.

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APPENDIX

Ambient Noise Spectra (5 - 40 kHz) Sonar Calibration Range (AUTEC)

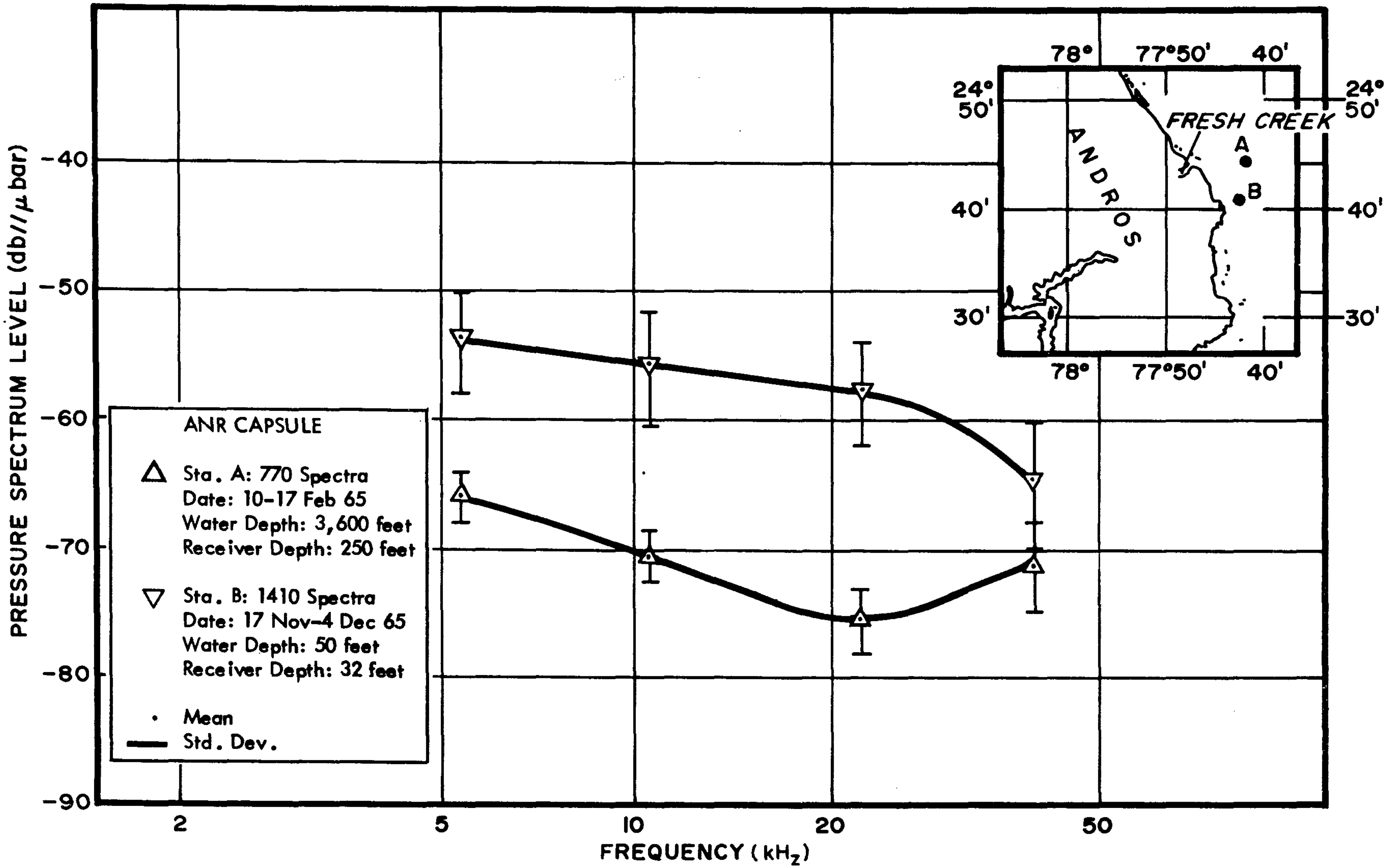
Shallow Water Ambient Noise Spectra in the Presence of Shipping and Snapping Shrimp (TOTO)

Shallow Water Ambient Noise Spectra (AUTEC Sonar Calibration Range)

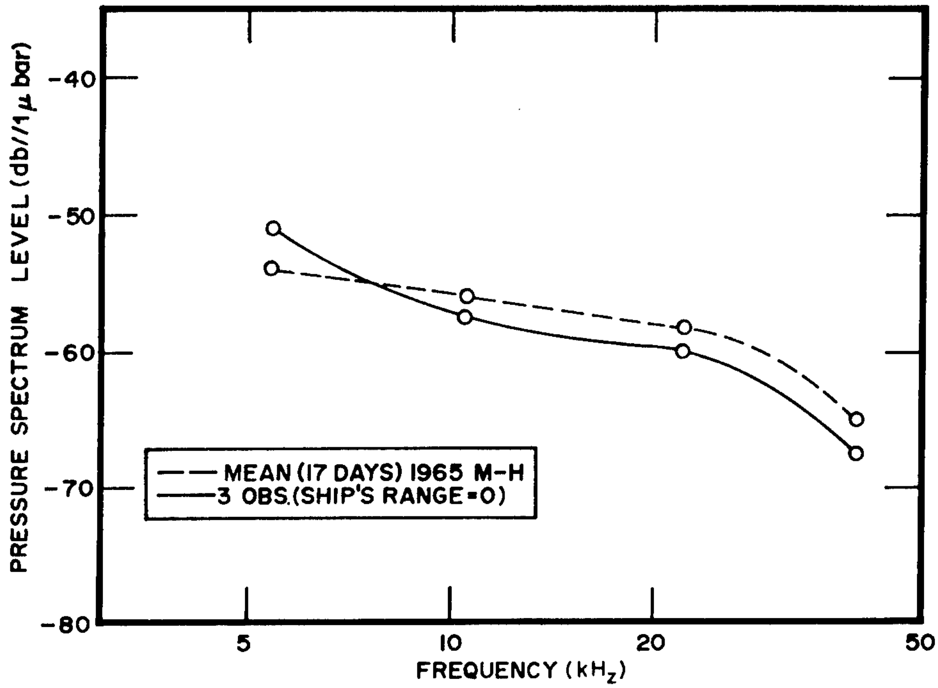
Time Variation of Ambient Noise in the AUTEC (5.4 - kHz) (Sonar Calibration Range)

Variations in Shallow Water Ambient Noise (10 kHz) in the Presence of Snapping Shrimp (TOTO)

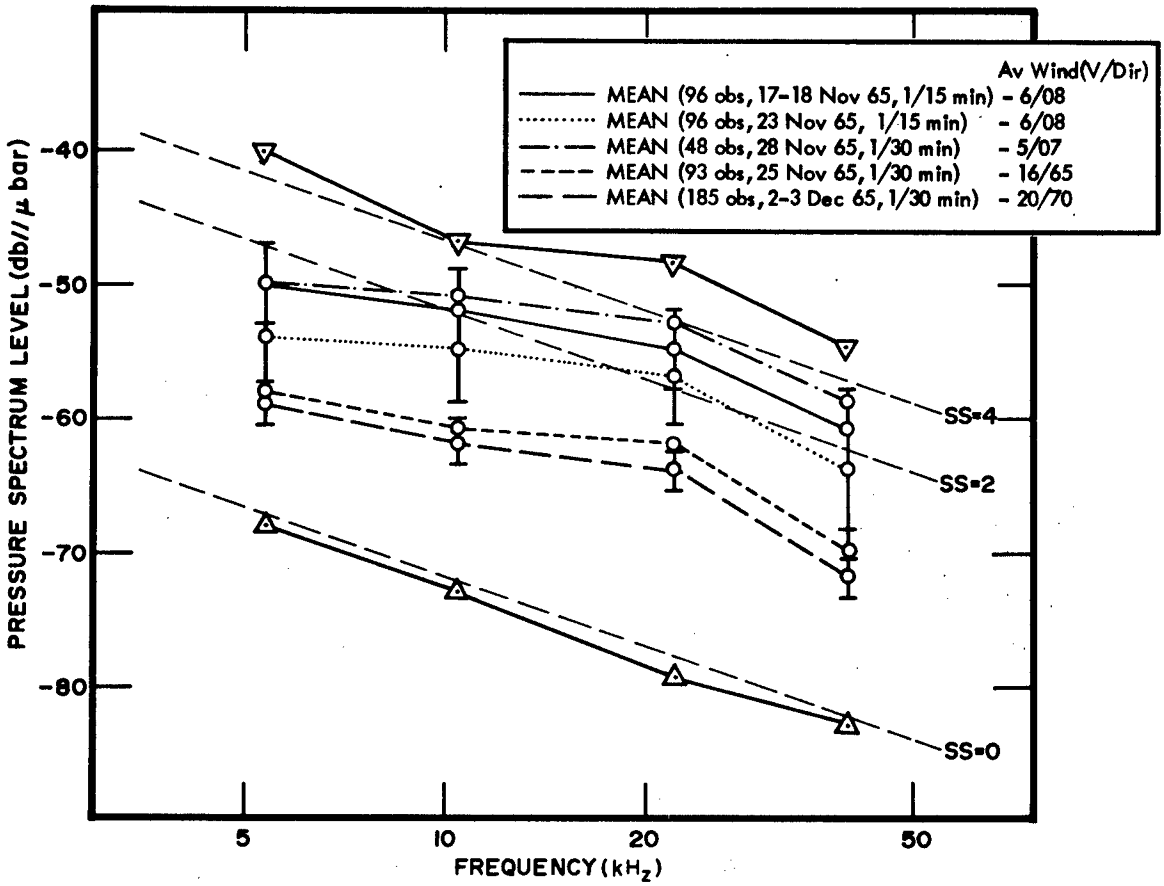
List of Wind Speeds and Directions in November 1965



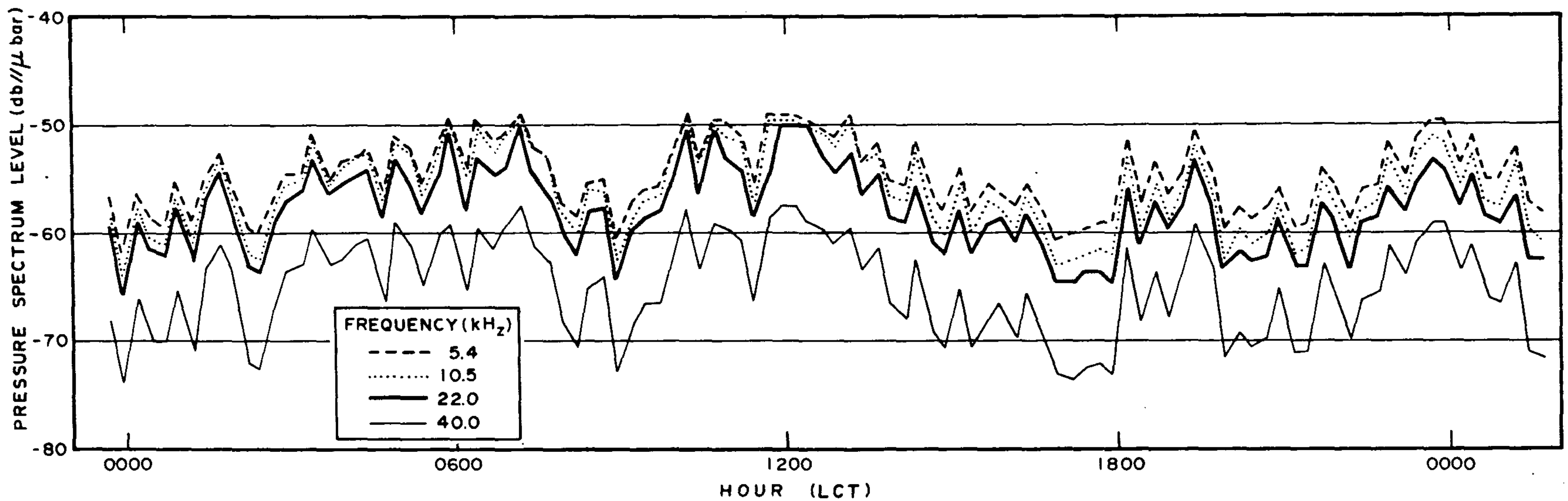
Ambient Noise Spectra (5 - 40 kHz); Sonar Calibration Range (AUTEC)



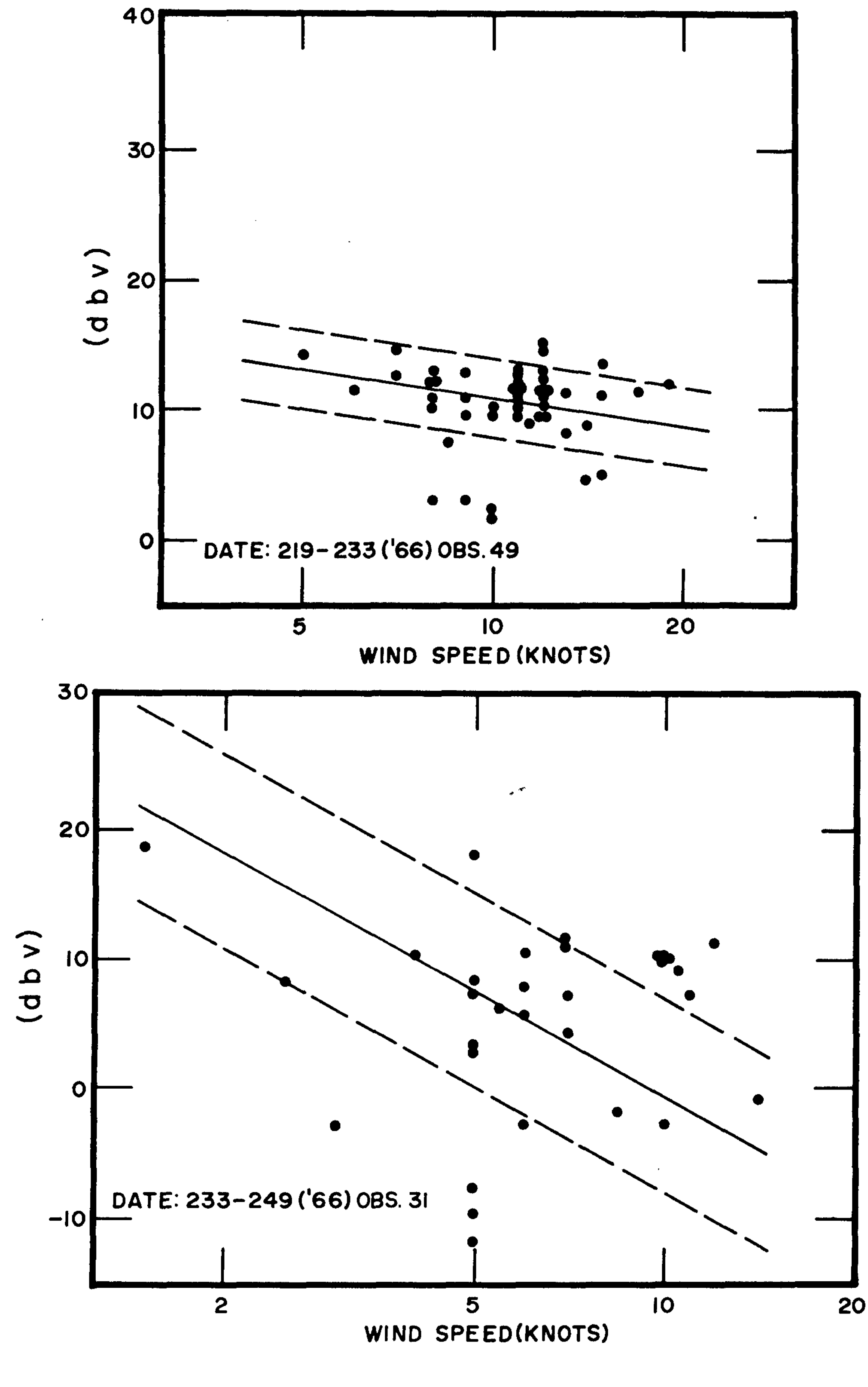
Shallow Water Ambient Noise Spectra in the Presence of Shipping and Snapping Shrimp (TOTO)



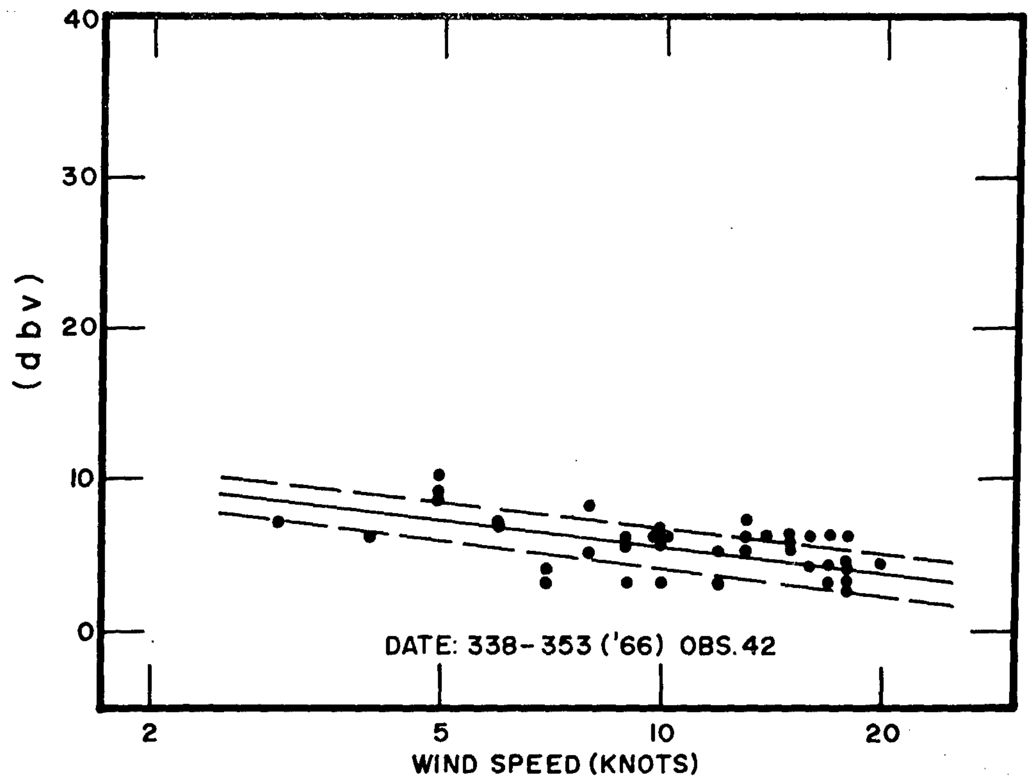
Shallow Water Ambient Noise Spectra
(AUTEC Sonar Calibration Range)

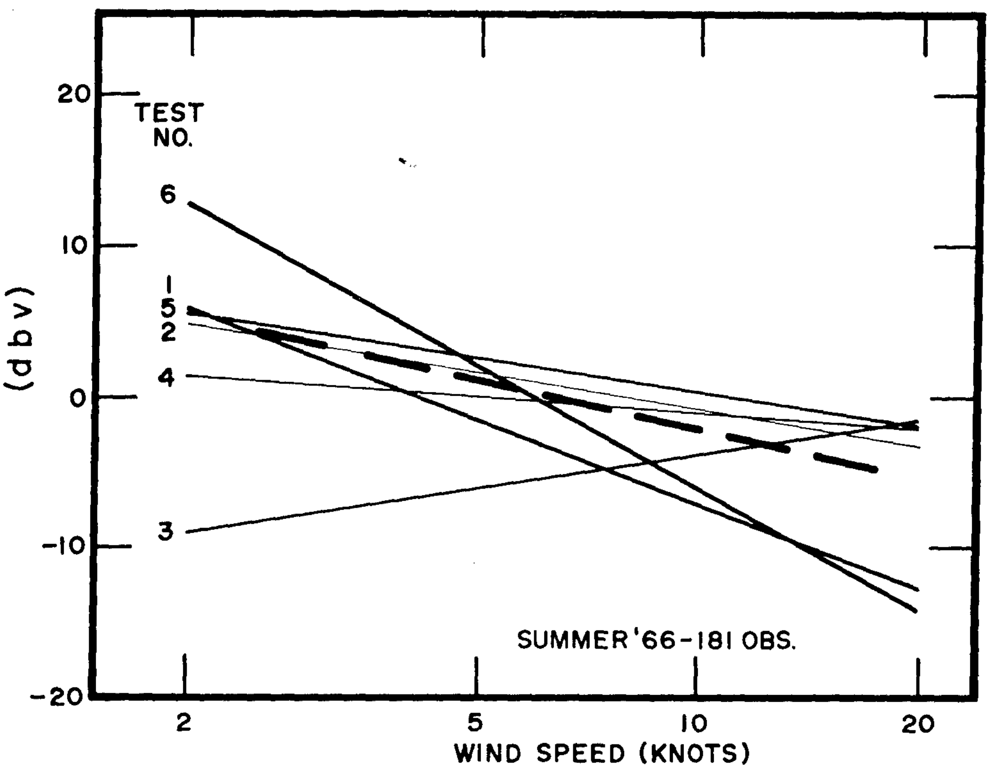


Time Variation of Ambient Noise in the AUTEC (5.4 - 40 kHz)
(Sonar Calibration Range)



Variations in Shallow Water Ambient Noise (10 kHz) in the Presence of Snapping Shrimp (TOTO)





Variations in Shallow Water Ambient Noise (10 kHz)
in the Presence of Snapping Shrimp (TOTO)

WIND SPEED AND DIRECTION
November 1965
(Basis for Figure 5)

Hour LCT	Day: 20th		21st		22nd		23rd		24th		25th	
	km	°T	km	°T	km	°T	km	°T	km	°T	km	°T
0400	05	270										
0500			06	280	06	320					15	060
0530	06	290			05	320					17	060
0600	05	265	06	280	03	320						
0630	04	260			03	320			15	040	16	060
0700	06	270					04	260	14	030		
0730	05	285			04	180						
0800					06	160	05	260	15	050		
0830			05	285			05	260	15	030	18	060
0900			04	285	06	160	07	290	15	040		
0930	03	285					07	290			17	060
1030	07	025									16	070
1100	04	110	06	070								
1230	07	105					13	030	13	030	18	070
1300			07	105	15	150						
1330			06	095			09	000				
1400			06	105	08	150			12	050	15	065
1500					11	200	10	000	13	040		
1530	06	115	08	120								
1600	06	110			12	220			16	070		
1700	06	180			09	180					15	060
1730							05	320	16	070		
1800					08	200			16	070		
1830					06	180	04	320	16	070		
1900					10	180						
2000							05	300			13	070
2030	08	320										
2100							05	260	18	065	14	060
2230			06	285								

Sustained Low	Transitional	Sustained High
0000 20 Nov – 1200 22 Nov	1200 22 Nov – 0000 24 Nov	0000 24 Nov – 0000 26 Nov
Average wind speed 5.5 knots	Average wind speed 7.9 knots	Average wind speed 15.3 knots
Av. noise level-51.21	Av. noise level-55.82	Av. noise level-60.01

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Security Classification

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1. ORIGINATING ACTIVITY (Corporate author) U.S. NAVAL OCEANOGRAPHIC OFFICE	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

SHALLOW WATER AMBIENT NOISE LEVELS IN THE TONGUE OF THE OCEAN, BAHAMAS, FALL OF 1965 AND SUMMER OF 1966

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Informal Report 8 November 1965 - 6 September 1966

5. AUTHOR(S) (First name, middle initial, last name)

JOHN S. WOODSON and WILLIAM J. REAVES, JR.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
August 1969	25	3

8a. CONTRACT OR GRANT NO. b. PROJECT NO. 959-XC c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) IR No. 69-57 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S. Naval Oceanographic Office

13. ABSTRACT

Ambient noise was monitored in shallow water east of Andros Island, Tongue of the Ocean, in November and December 1965 and September 1966. Data were collected with an encapsulated, self-recording device and a stand-mounted hydrophone connected by cable to shore-based instrumentation.

The prime noise generator was found to be snapping shrimp. Shrimp noise was high during light winds and low during winds approaching gale force. During winds of whole gale force, a sevenfold increase in noise level can be expected over that observed for normal weather conditions. Shipping was an insignificant contributory noise source at frequencies in the 5 - 10 kHz range. The noise level was slightly higher during cold weather months as indicated by the November-December 1965 mean of -55.5 db at 10 kHz and the September 1966 mean of -63.3 db at 10 kHz.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
AMBIENT NOISE TONGUE OF THE OCEAN AUTEC MINNEAPOLIS - HONEYWELL AMBIENT NOISE CAPSULE SHALLOW WATER ACOUSTIC MONITOR (SWAM)						

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